

*Water source:* Lake Pend Oreille provides the vast majority of flow through the study area, both historically and currently. At Newport, the most upstream reach in Washington and situated below Albeni Falls dam, river temperatures are cooler now than what is predicted to have occurred naturally. This is due to the dam maintaining the lake level in the mid and late summer higher than what it would have been under natural conditions. The higher lake level allows for deeper, cooler water from the lake to enter the Pend Oreille River. This cool water buffers sources of river warming from Newport to Blueslide so that river temperatures are cooler now than before the dams were built. Box Canyon and Boundary dams also depress the maximum temperatures observed in their associated tailrace reaches by withdrawing cooler subsurface water from their forebays and discharging it downstream after power generation.

*Hydraulic changes:* Because of the dams the river is now deeper and wider, with lower average velocities in comparison to what occurred naturally. These changes are most evident during the critical summer months when the warmest temperatures occur. This increased storage now buffers the river from large temperature fluctuations and is one of the reasons why cooler temperatures found at Newport (downstream of the Albeni Falls tailrace) can now be observed in temperature profiles 40 miles down-river at Blueslide. These hydraulic characteristics also buffer temperature changes associated with alterations in mainstem or tributary shading and the presence of NPDES discharges. In comparison, the Pend Oreille River's natural channel flow characteristics were narrower and shallower and subject to greater gains and losses in heat which, in turn, affected the range in temperature.

#### **Temperature criteria exceedances**

Despite the hydraulic changes and their overall effect on buffering temperature shifts, the temperature criteria for the Pend Oreille River was exceeded in particular reaches (Table ES-2). This occurred most prominently in the forebays of Box Canyon and Boundary dams, where Part 1 of the criteria, concerning maximum temperatures, was exceeded by an average (2004, 2005) of 0.94°C and 0.59°C, respectively.

*State line:* Ecology set an assumption to comply with 2004 existing temperatures at the Idaho-Washington Stateline. Setting this allocation protects the river from additional heating upstream and ensures viability of allocations downstream.

*Hydroelectric facilities:* When natural condition river temperatures are greater than 20°C (July and August), load allocations have been set equivalently at 0.12°C above the natural temperature condition for the Box Canyon and Boundary facilities due to the inter-relationship of the temperature impacts and the associated cumulative impacts in the watershed. The temperature reduction required to achieve the load allocations for Box Canyon and Boundary is 1.13°C and 0.76°C, respectively, based on 2004 results. These reductions apply during July and August in the forebays of the dams, which are the areas of maximum temperature impairment.

## **Who should participate in this TMDL?**

The Pend Oreille Public Utility District (PUD) and Seattle City Light own and operate Box Canyon Dam and Boundary Dam, respectively.

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Ecology collected temperature and other environmental data for this TMDL in 2004 from the Idaho-Washington Stateline to Box Canyon Dam.

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Within the Box Canyon model, data was generated at 336 locations, or segments, from the Idaho/Washington border to the Box Canyon facility.

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The dams have altered the hydrologic characteristics of the river from the natural condition. Not only has the volume of water increased, but there is also a difference in flows. These differences between the natural and existing conditions makes direct time-based (i.e. day-to-day) temperature comparisons difficult. For example, Battelle's Pacific Northwest National Laboratory calculated that the time of travel through the Boundary Dam reservoir is about a half day under natural conditions, whereas with the dam in place the travel time is approximately two and a half (2.5) days (Breithaupt et al., 2008). In addition, Boundary Dam is operated in a peaking mode (high flows during the day and near-zero at night) and Box Canyon is a run-of-the-river operation. The cumulative frequency distribution minimizes these differences and so allows different hydrologic conditions to be compared.

The effect of short-term events such as weather fronts are minimized; Breithaupt et al. (2008) also analyzed the temperature response in the Boundary reservoir and found that under natural conditions the response is less than one day, and under existing conditions (with the dam) the response is about four and a half (4.5) days.

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However, because the Pend Oreille River is affected by discharges from dams in both Washington and Idaho, Ecology used the modeled natural condition, which represents the unaffected river, to represent T in this TMDL.

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The results for Scenario 4.0, the effect on the existing condition provided the absence of the Box Canyon and Boundary hydroelectric facilities, will be presented in the main text.

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The modifiers included: the hydroelectric facilities (Box Canyon and Boundary dams), riparian shade, and NPDES discharges.

As observed, in terms of the Blueslide reach in 2004, maximum temperature conditions increased without the Box Canyon facility in place.

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In fact, overall, maximum temperatures observed at the majority of the upper river reaches are cooler now than what occurred naturally.

Of the study reaches, Tiger and Box Canyon forebay display the most chronically elevated heating pattern (Figure 15). Throughout the range in temperatures observed for these reaches, the existing condition is warmer than what occurred naturally, a pattern not observed for the other reaches. This condition was most evident at the Box Canyon forebay (Figure 15).

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Once this cooler water is passed below Albeni Falls, the increased river volume due to the impoundments buffers the river from temperature variation. This is why even at Blueslide, approximately 40-miles below Newport, the overall existing condition remains cooler than the natural condition by about 0.7°C.

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The cooler temperatures noted downstream of the Albeni Falls and Box Canyon facilities are also present at Boundary Dam.

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These factors included the influence of: NPDES discharges, tributary and mainstem shade, and the Box Canyon and Boundary hydroelectric facilities (Table 4).

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The vast majority of the Pend Oreille River's flow is introduced at its origin, the outflow from Lake

Pend Oreille, with relatively minor tributary additions through the reaches. Regarding the study area, the temperature conditions of the river following the discharge from Albeni Falls first establishes a base temperature condition, and that condition is largely buffered from modification due to the river's now changed hydraulics: primarily associated with the greater channel storage (deeper water column) as a consequence of the Box Canyon and Boundary hydroelectric facilities. It is really only the hydroelectric facilities that overcome these temperature buffering

characteristics to cause significant temperature shifts.

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Survey results indicate that water temperatures reached 30°C within the side-channel. This side-channel is likely a historic meander channel of the river that has become inundated due to the backwater effect of Box Canyon dam. Within the side channel, the depth of flow is relatively shallow in comparison to the main channel, and has a low velocity. These characteristics result in the elevated observed temperatures. Without the dam in place, and the backwater effect removed, the level of flow through this side channel is substantially reduced and, in the process, the overall maximum temperatures through the segments comprising the Skookum reach are significantly reduced.

However, by the Tiger reach this effect is offset by the larger influence of the Box Canyon facility. With its absence, maximum temperatures in the Tiger and Box Canyon Forebay reaches decline significantly by an average (2004 / 2005) of 0.50°C and 0.96°C, respectively throughout the range of maximum temperatures observed (20-26°C) (Table 9 and Figure 28). These temperature decreases were large enough to result in achievement of the criteria for both reaches (Figure 28).

As previously discussed, the Albeni Falls facility has a similar affect on the Box Canyon reaches, though of a lower magnitude. This effect of colder water withdrawal and downstream discharge occurring at each of the hydroelectric facilities is clearly displayed at the Boundary tailrace reach.

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It is important to note that Scenario 4.0 always maintains an upstream hydroelectric facility in place; Albeni Falls for the Box Canyon reaches and Box Canyon for the Boundary reaches. Even with the absence of the downstream hydroelectric facility, the majority of the daily maximum temperatures remain below those that occurred naturally (Figures 27-29). The reason for this is the cooling effect of the discharge of colder subsurface water associated with each of the upstream hydroelectric facilities.

Paradoxically, the upstream storage that results in cold water discharge, depressing the highest downstream maximum temperatures, also leads to increased heating at the lowest maximum temperatures. The reason for this is that the Pend Oreille River under the natural condition was shallower and therefore able to gain and lose heat at a greater rate in comparison to the existing condition with its increased volume and heat storage capacity. Heat is now gained and lost at a slower rate as a consequence of this storage. In late August, under the natural condition, the temperature of the river dropped at a faster rate than it does now, leading to a positive temperature differential (gain in heat in relation to the natural condition). This separation is present in the graphics and is characterized by the positive temperature differential present for the lowest maximum temperature percentiles. It is particularly prominent in the temperature differential profiles for the Boundary reaches.

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While the absence of the Box Canyon facility decreases maximum temperatures at segment 115, the result is an increase at segment 172.

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Ecology developed an assumption for the summer critical period at the state line. The assumption is that existing river temperatures will continue to be cooler now than under natural conditions. Ecology assumes river temperatures entering Washington at the Idaho-Washington state line will be consistent with 2004 observed temperatures during low flow and warm weather conditions (Figure 32). The state line assumption provides a baseline for establishing allocations downstream. Therefore, Ecology is not *Pend Oreille Temperature Water Quality Improvement Report* assigning a portion of the 0.3°C allowance to the state line during the summer critical period. An assumption during the fall critical period is not required.

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### Hydroelectric facilities

Study results indicate that the operations of the Pend Oreille Public Utility District's Box Canyon Dam and Seattle City Light's Boundary Dam are associated with increased heat loads in the Pend Oreille River. In both cases the increase is significant enough to result in the exceedance of the Pend Oreille River temperature criteria. Among the 12 river reaches examined as part of this study, the forebays of both facilities had the greatest level of temperature exceedance. The highest maximum temperatures were observed at the Box Canyon forebay where temperatures were found to chronically exceed the criteria throughout the maximum range examined. In comparison, maximum temperatures observed at the Boundary forebay were less chronically elevated, though it appears that the facility is the beneficiary of proximity.

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